BITS-PILANI, DUBAI
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
SECOND SEMESTER 2007-2008

COMPREHENSIVE EXAMINATION

ES UC 242 STRUCTURE AND PROPERTIES OF MATERIALS

Date: 29-05-2008 | **Time: 3 hrs.**
Marks: 80 | **Weightage: 40%**

Note: 1. Answer all questions.
2. Marks are shown in the brackets against each question.
3. Answer Part A (Blue answer book), Part B (Green answer book), Part C (Brown answer book) and Part D (Blue answer book)
4. Use the tables and figures, attached, wherever necessary.

PART-A

.a Explain briefly the mechanism of electrochemical corrosion. [2]

b Niobium forms a substitutional solid solution with vanadium. Compute the number of Niobium atoms per cubic centimeter for a Niobium-Vanadium alloy that contains 24 wt% Nb & 76 wt% V. Also derive the equation used. [8]

2.a. State the Flick's First law of diffusion. [2]

b Nitrogen from the gaseous phase is to be diffused in to pure iron at 700 °C. if the surface concentration is maintained at 0.1 wt% N, what will be the concentration 1 mm from the surface of water after 10h? The diffusion coefficient for nitrogen in iron at 700 °C is 2.5X 10^{-11} m^2/s [8]

PART – B

3.a A metal is deformed in a tension test into its plastic region. The starting specimen had a gage length = 2.0 cm and an area 0.50 sq. cm. At one point in the tensile test, the gage length = 2.5 cm and the corresponding engineering stress = 24000 Pa at another point in the test prior to necking, the gage length = 3.2 cm and the corresponding engineering stress = 28000 Pa. Determine the strain-hardening exponent. [4]

b. Using TTT curves, describe what transformations happen in:
i. Path 1, ii. Path 2 , iii. Path 3 and iv. Path 4 [6]

4 a Mention the allotrophic changes taking place in iron from Iron-Carbon diagram [2]

b. Given the Fe-Fe_3C phase diagram, calculate the phases present at the eutectoid composition line at:
i.) T = 3000°F ii.) T = 2200°F iii.) T = 1333°F and iv.) T = 410°F [8]

PART – C

5 a. The total resistivity of a deformed Cu-Ni alloy is 2.6×10^{-8} Ω-m. If the thermal resistivity is 0.9×10^{-8} Ω-m and the presence of Ni gives a resistivity of 1.38×10^{-8} Ω-m, what is the electrical resistivity due to deformation? [4]

b. The density of totally crystalline polyvinylchloride at room temperature is 1.293 g/cc. Also at room temperature, the unit cell for this material is triclinic with lattice parameters:
a=0.597 nm, b=0.547 nm, c=1.618 nm, α= 48.4°, β=76.6° and γ=62.5°
If the volume of a triclinic unit cell V_{tri} is a function of these lattice parameters as
$V_{tri}= abc\sqrt{1-\cos^2\alpha \ -\cos^2\beta \ -\cos^2\gamma+2\cos\alpha\cos\beta\cos\gamma}$ determine the number of mer units per unit cell. [8]

6 Compute the weight percent of sulfur that must be added to completely crosslink an alternating cis-isoprene / butadiene co polymer assuming that 5 sulfur atoms participate in each cross link [8]

PART – D

7 a. Calculate the radius of an iridium atom and derive the formula for volume of unit cell interms of atomic radius. Iridium has an FCC crystal structure, a density of 22.4 g/cm³, and an atomic wt of 192.2 g/mol. [6]

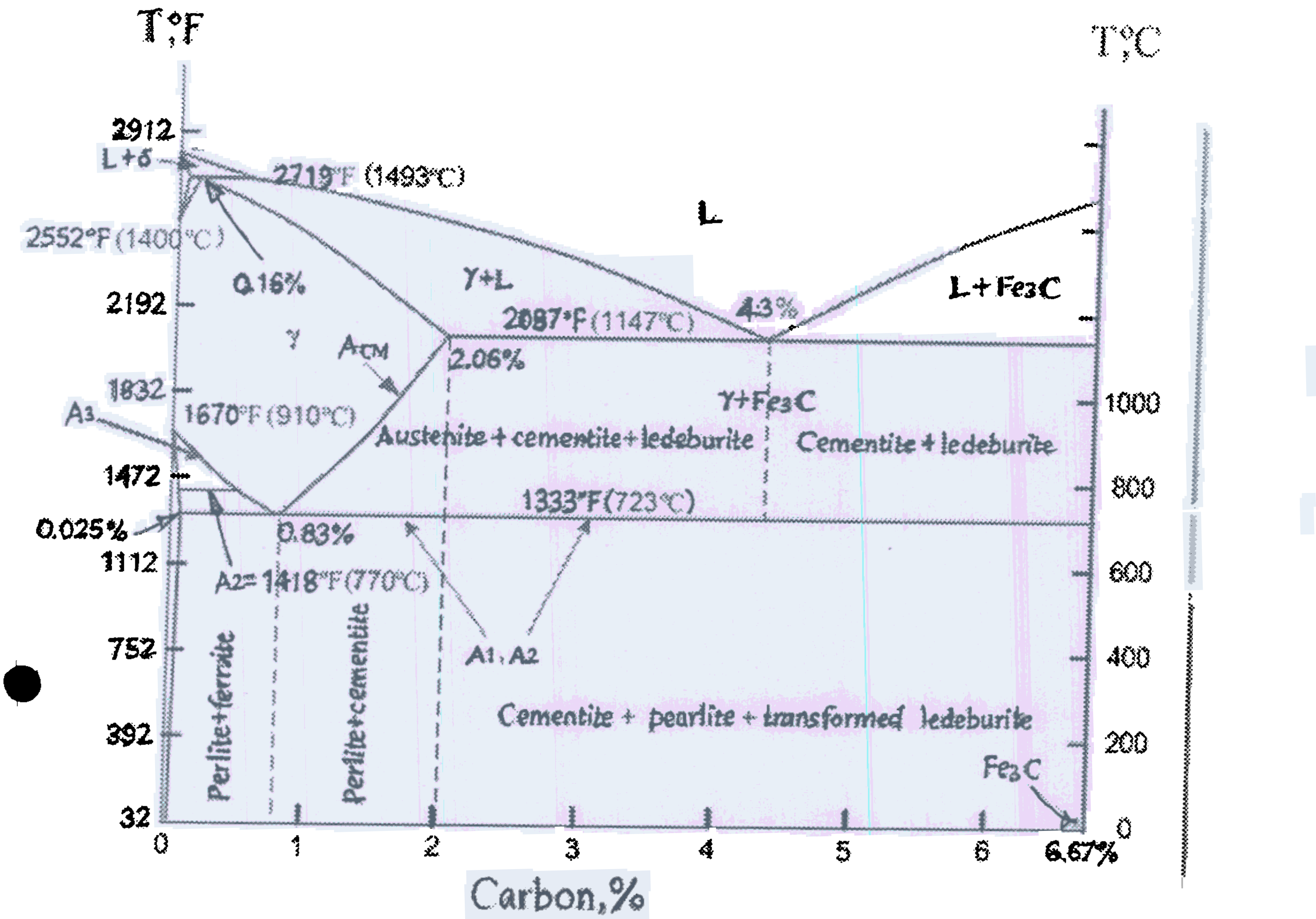
b. A single crystal of zinc is oriented for a tensile test such that its slip plane normal makes an angle of 65^0 with the tensile axis. Three possible slip directions make angles of 30^0, 48^0, and 78^0 with the same tensile axis. Which of these three slip directions is most favored? If plastic deformation begins at a tensile stress of 2.5 MPa, determine the critical resolved shear stress for zinc. [6]

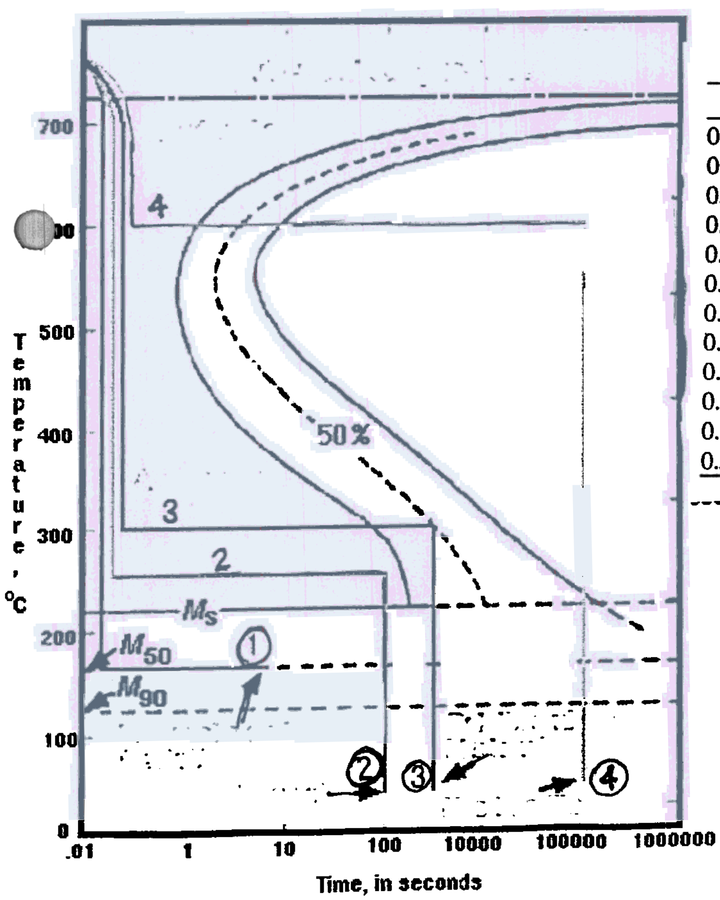
8 A hypothetical AX type of ceramic material is known to have a density of 2.10 g/cm^3 and a unit cell edge length of 0.57 nm. The atomic weights of A and X elements are 28.5 and 30.0 g/mol respectively. Identify the crystal structure with justification. [8]

Characteristics of Selected Elements

Element	*Symbol*	*Atomic Number*	*Atomic Weight (amu)*	*Density of Solid, 20°C (g/cm^3)*	*Crystal Structure, 20°C*	*Atomic Radius (nm)*	*Ionic Radius (nm)*	*Most Common Valence*	*Melting Point (°C)*
Aluminum	Al	13	26.98	2.71	FCC	0.143	0.053	3+	660.4
Argon	Ar	18	39.95	—	—	—	—	Inert	−189.2
Barium	Ba	56	137.33	3.5	BCC	0.217	0.136	2+	725
Beryllium	Be	4	9.012	1.85	HCP	0.114	0.035	2+	1278
Boron	B	5	10.81	2.34	Rhomb.	—	0.023	3+	2300
Bromine	Br	35	79.90	—	—	—	0.196	1−	−7.2
Cadmium	Cd	48	112.41	8.65	HCP	0.149	0.095	2+	321
Calcium	Ca	20	40.08	1.55	FCC	0.197	0.100	2+	839
Carbon	C	6	12.011	2.25	Hex.	0.071	~0.016	4+	(sublimes at 3367)
Cesium	Cs	55	132.91	1.87	BCC	0.265	0.170	1+	28.4
Chlorine	Cl	17	35.45	—	—	—	0.181	1−	−101
Chromium	Cr	24	52.00	7.19	BCC	0.125	0.063	3+	1875
Cobalt	Co	27	58.93	8.9	HCP	0.125	0.072	2+	1495
Copper	Cu	29	63.55	8.94	FCC	0.128	0.096	1+	1085
Fluorine	F	9	19.00	—	—	—	0.133	1−	−220
Gallium	Ga	31	69.72	5.90	Ortho.	0.122	0.062	3+	29.8
•Germanium	Ge	32	72.59	5.32	Dia. cubic	0.122	0.053	4+	937
Gold	Au	79	196.97	19.32	FCC	0.144	0.137	1+	1064
Helium	He	2	4.003	—	—	—	—	Inert	−272 (at 26 atm)
Hydrogen	H	1	1.008	—	—	—	0.154	1+	−259
Iodine	I	53	126.91	4.93	Ortho.	0.136	0.220	1−	114
Iron	Fe	26	55.85	7.87	BCC	0.124	0.077	2+	1538
Lead	Pb	82	207.2	11.35	FCC	0.175	0.120	2+	327
Lithium	Li	3	6.94	0.534	BCC	0.152	0.068	1+	181
Magnesium	Mg	12	24.31	1.74	HCP	0.160	0.072	2+	649
Manganese	Mn	25	54.94	7.44	Cubic	0.112	0.067	2+	1244
Mercury	Hg	80	200.59	—	—	—	0.110	2+	−38.8
Molybdenum	Mo	42	95.94	10.22	BCC	0.136	0.070	4+	2617
Neon	Ne	10	20.18	—	—	—	—	Inert	−248.7
Nickel	Ni	28	58.69	8.90	FCC	0.125	0.069	2+	1455
Niobium	Nb	41	92.91	8.57	BCC	0.143	0.069	5+	2468
Nitrogen	N	7	14.007	—	—	—	0.01–0.02	5+	−209.9
Oxygen	O	8	16.00	—	—	—	0.140	2−	−218.4
Phosphorus	P	15	30.97	1.82	Ortho.	0.109	0.035	5+	44.1
Platinum	Pt	78	195.08	21.45	FCC	0.139	0.080	2+	1772
Potassium	K	19	39.10	0.862	BCC	0.231	0.138	1+	63
Silicon	Si	14	28.09	2.33	Dia. cubic	0.118	0.040	4+	1410
Silver	Ag	47	107.87	10.49	FCC	0.144	0.126	1+	962
Sodium	Na	11	22.99	0.971	BCC	0.186	0.102	1+	98
Sulfur	S	16	32.06	2.07	Ortho.	0.106	0.184	2−	113
Tin	Sn	50	118.69	7.17	Tetra.	0.151	0.071	4+	232
Titanium	Ti	22	47.88	4.51	HCP	0.145	0.068	4+	1668
Tungsten	W	74	183.85	19.3	BCC	0.137	0.070	4+	3410
Vanadium	V	23	50.94	6.1	BCC	0.132	0.059	5+	1890
Zinc	Zn	30	65.39	7.13	HCP	0.133	0.074	2+	420
Zirconium	Zr	40	91.22	6.51	HCP	0.159	0.079	4+	1852

Avagadro's number = 6.023×10^{23} atoms/mol.





Tabulation of Error Function Values

z	erf(z)	z	erf(z)	z	erf(z
0	0	0.55	0.5633	1.3	0.934
0.025	0.0282	0.60	0.6039	1.4	0.952
0.05	0.0564	0.65	0.6420	1.5	0.966
0.10	0.1125	0.70	0.6778	1.6	0.976
0.15	0.1680	0.75	0.7112	1.7	0.983
0.20	0.2227	0.80	0.7421	1.8	0.989
0.25	0.2763	0.85	0.7707	1.9	0.992
0.30	0.3286	0.90	0.7970	2.0	0.995
0.35	0.3794	0.95	0.8209	2.2	0.998
0.40	0.4284	1.0	0.8427	2.4	0.999
0.45	0.4755	1.1	0.8802	2.6	0.999
0.50	0.5205	1.2	0.9103	2.8	0.999

BITS-PILANI, DUBAI
DUBAI INTERNATIONAL ACADEMIC CITY, DUBAI
SECOND SEMESTER 2007-2008
T E ST – I I (Open Book)
ES UC 242 Structure and Properties of Materials

Date: 13-04-2008 **Time: 50 minutes**
Marks: 40 **Weightage: 20%**

Note: 1. Answer all questions.
2. Marks are shown in the brackets against each question.
3. Prescribed Text book and hand-written Class notes are only allowed.

1 Vanadium forms a substitutional solid solution in iron for concentrations up to approximately 38 wt% vanadium at room temperature. Determine the concentration in wt% of vanadium that must be added to iron to yield a unit cell edge length of 0.292 nm. **[10]**

2 For nitriding of steel, nitrogen is to be supplied from an external nitrogen rich gas at an elevated and constant temperature. The initial nitrogen content of steel is 0.002 wt% whereas the surface concentration is to be maintained at 0.50 wt%. In order for this treatment to be effective, a nitrogen content of 0.10wt% must be established at a position of 0.40mm below the surface. Specify the appropriate treatments in terms of time at 500°C. The pre exponential and activation energy for the diffusion of nitrogen in iron are 3 $x10^{-7}$ m^2/s and 76150 J/mol respectively over the temperature range.

[12]

3 The stress at which plastic deformation begins for a bronze specimen of length 76 mm is 345 MPa and its modulus of elasticity is 103 GPa.
(a) What is the maximum load that may be applied to the specimen with a cross sectional area of 130 mm^2 without plastic deformation?
(b) Calculate the maximum length to which the specimen may be stretched without causing plastic deformation.
(c) Find the true strain at a true stress of 400 MPa if the constant **K** in the true stress-true strain equation is 1030 MPa. **[10]**

4 The lower yield point for an iron that has an average grain diameter of $5x10^{-2}$ mm is 135 MPa. At a grain diameter of $8x10^{-3}$ mm, the yield point increases to 260 MPa. At what grain diameter will the lower yield point be 205 MPa? **[8]**

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SECOND SEMESTER 2007-2008
T E ST – I (Closed Book)
ES UC 242 Structure and Properties of Materials

Date: 24-02-2008 **Time: 50 minutes**
Marks: 50 **Weightage: 25%**

Note: 1. Answer all questions.
2. Marks are shown in the brackets against each question.

Question 1

(a) Calculate the force of attraction between Ca^{2+} and O^{2-} ion centres of which are separated by a distance of 1.25nm. $e = 1.6 \times 10^{-19}$ C, $\epsilon_0 = 8.85 \times 10^{-12}$ F/m **[6]**

(b) The net potential energy between two adjacent ions may be represented by

$$E_N = -A/r + B/r^n$$

Derive expressions for E_o (bonding energy) and r_o (equilibrium spacing) in terms of A, B and n. **[6]**

Question 2

(a) Derive the expression for the relationship between lattice parameter 'a' and atomic radius 'R' for BCC. **[6]**

(b) Calculate the radius of an Iridium atom given that Ir has an FCC structure, a density of 22.4 g/cm^3 and an atomic weight of 192.2 g/mol, $N_A = 6.023 \times 10^{23}$ atoms/mol **[6]**

Question 3

(a) Derive linear density expressions for FCC [100] and [111] directions in terms of atomic radius R. **[6]**

(b) Compute the values of linear density for the above directions for copper (Atomic radius=0.128 nm) **[6]**

Question 4

(a) From Fig. 4a, determine the indices for the two directions indicated by the two vectors. **[7]**

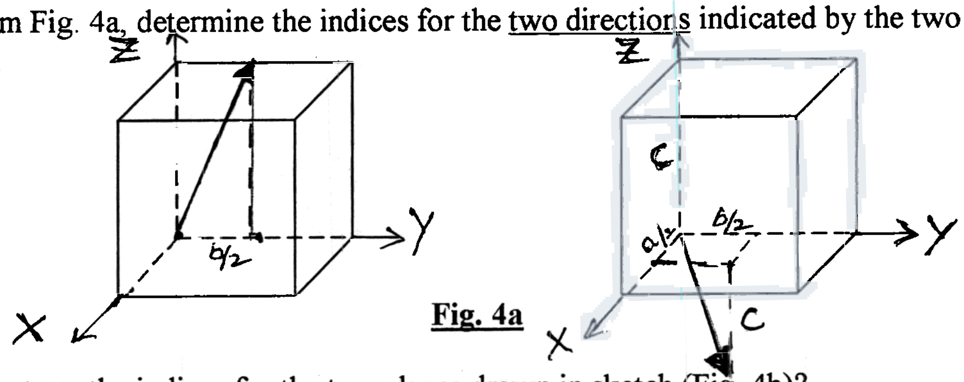

Fig. 4a

(b) What are the indices for the two planes drawn in sketch (Fig. 4b)? **[7]**

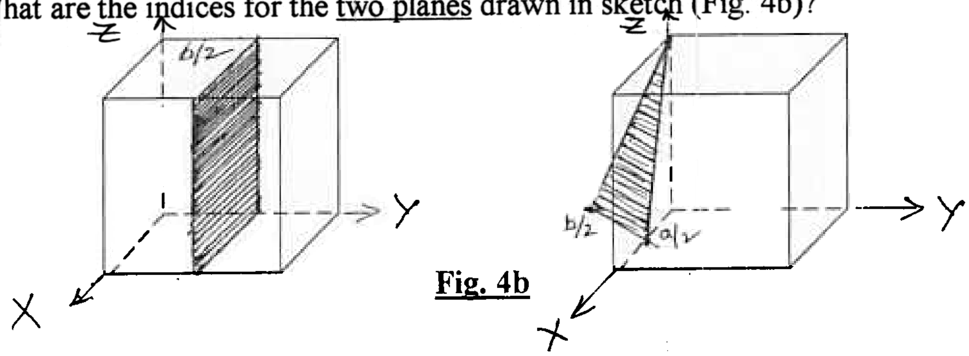

Fig. 4b